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Stream Habitat Improvement and Native Southwestern Trouts

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Log stream improvement structures in two streams containing Gila trout (*Salmo gilae* Miller) increased physical habitat factors (volume, cover, depth) and positively influenced populations of this endangered trout. Results of analyses of habitat improvement for the Gila trout may have similar management implications for Arizona trout (*Salmo apache* Miller) and for both delisting and developing quality sport fisheries for these two rare southwestern trouts.

Keywords: Habitat improvement, *Salmo gilae, Salmo apache*

Habitat improvement for salmonids began in the 1930's when CCC workers constructed thousands of stream improvement structures throughout the United States (Tarzwell 1938, Ehlers 1956). Although the results of these activities have not always been measured, the structures have generally been accepted as having a positive effect on fishing and the fish resource, and the practices are used widely in managing trout streams today. Tarzwell (1936) aptly stated, "It is much easier to install a so-called improvement than it is to determine whether or not it is beneficial."

Tarzwell (1938) evaluated the effect of stream improvement on trout numbers and growth rates and on the aquatic macroinvertebrate fauna in the Southwest. His investigations disclosed that stream improvements increased both the number and pounds of trout based on creel census and the standing crop of bottom organisms. He recommended log dams for improving trout habitat in southwestern streams.

The USDA Forest Service and game and fish departments of Arizona and New Mexico, as the principal managers of the habitat and the fish resource in stream environments, have also examined the effects of stream improvement. These studies have suggested both positive (McKirdy 1963, 1964; Harrison 1962) and neutral (Carufel 1964) effects on trout populations and angling.

Since 1977 the USDA Forest Service has been studying the habitat requirements and biology of two native southwestern trouts (Rinne 1977).[2] The Arizona trout (*Salmo apache*) and the Gila trout (*S. gilae*) are currently listed as threatened and endangered, respectively (USDI 1980). Their status results mainly from hybridization and competitive interactions with non-native trouts and chars, principally rainbow trout (*S. gairdneri*), brown trout (*S. trutta*), and brook trout (*Salvelinus fontinalis*). As a result, the two native trouts persist only in extreme headwater tributaries, some of which have, or are suitable for, log-dam improvement structures. While doing basic habitat evaluation for the Gila trout and examining its movements in two streams (McKnight and Main Diamond Creeks) in the Gila National Forest, New Mexico, Rinne (1978, 1980) collected information that permitted limited evaluation of log structures for improving habitat and the trout resource.

Methods and Materials

Data on each habitat and fish resource variable compared are from both natural pools and those created below log-dam structures. Methodology for determination of the trout resource and for delineating the habi-

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[2]*Rinne, John N. 1977. Habitat requirements, biology and distribution of the native Arizona (*Salmo apache *Miller) and Gila (*Salmo gilae *Miller) trouts. Rocky Mountain Forest and Range Experiment Station, Study Plan RM 1710-62. 29 p. Tempe, Ariz.*

tat are discussed in Rinne (1978). Basically, the procedure follows these steps: (1) Block pools with nets and electrofish three times, (2) record numbers, lengths, weights, and total biomass of fish, (3) compute surface area from measurements of parallel and perpendicular transects, (4) estimate pool volume and depth statistics from depth measurements on transects, and (5) compute the area of instream and streambank cover from dimension measurements. Habitat and the fish resource in natural versus artificial pools were compared by an unpaired T-test.

Results

In McKnight Creek, there was significantly more volume (unpaired T-test; $P = 0.05$) in artificial than in natural pools (table 1). This was not true in Main Diamond Creek. The remaining three habitat variables (cover, maximum and mean depth) were significantly different ($P = 0.01$) between natural and artificially created pools in both streams. In Main Diamond Creek, number and biomass of Gila trout paralleled improved habitat, and both were significantly greater ($P = 0.01$) in log-structure than in natural pools. By comparison, in McKnight Creek biomass and mean and maximum size of trout were significantly greater ($P = 0.05$) in pools below log structures.

In different terms, volume was 50% to 70% greater in pools created by stream improvement structures in the two streams than in naturally occurring pools. In Main Diamond Creek, cover was seven times as great in artificial pools as in natural pools. In McKnight Creek, cover in artificial pools was over 1.5 times greater than in natural pools in that stream. Mean depth of pools below structures (27 cm) compared to natural pools (14 cm) was twice as great in Main Diamond Creek and 38% to 50% greater in McKnight Creek. There were 1.5 times more Gila trout and 2.25 times the biomass in artificially created pools in Main Diamond Creek as in natural pools. Biomass was twice as great in McKnight Creek in log-dam as in natural pools, but the number of fish was on an average only 30% greater. Mean and maximum size of fish in both streams were, on an average, 20% greater in artificial than in natural pools.

Discussion and Management Implications

The Gila trout is basically a pool fish, and cover and volume and depth of pools have been demonstrated to be positively correlated to both number, size, and biomass of this species of trout (Rinne 1978). Any increase in these three physical habitat factors should positively affect the species in terms of numbers and size of individuals. This occurred in the two streams studied in New Mexico. That is, there was more basic physical habitat below log structures, and twice as many Gila trout occupied these artificial pools. In addition, in small headwater tributaries in the Southwest, pools appear very important to both the native trouts in times of drought and harsh winter weather.

Cover has been widely documented as beneficial to trout (Boussu 1954, Wesche 1976, Binns and Eiserman 1979). The doubling of cover in McKnight Creek and seven-fold increase in this variable in log-dam pools in Main Diamond Creek contributed to increased Gila trout populations.

Size of Gila trout has been positively correlated with maximum depth of pools (Rinne 1978). Maximum and mean size of Gila trout was greater (ca. 25%) in created pools compared to natural pools, in part because of the 40% to 100% greater mean and maximum depth of the former. The positive relationship between maximum depth of pool and maximum size of Gila trout could have important management implications relative to a future sport fishery for this now-endangered trout. That is, reclamation of downstream waters (with deeper pools) or introductions of Gila trout into lakes (as has been done with Arizona trout) may be desirable. The Arizona trout normally attains a length of less than 200 mm in stream

Table 1.—Comparison of habitat and the fish resource of natural pools and those created by stream improvement structures in Main Diamond and McKnight Creeks, Gila National Forest, New Mexico

Characteristic	Main Diamond Creek ($DF = 13$)[1]		McKnight Creek ($DF = 28$)[1]	
	Artificial pools	Natural pools	Artificial pools	Natural pools
Habitat		$\bar{x} \pm 1SD$		
Volume (m³)	3.45 ± 0.85	2.31 ± 0.55	4.67 ± 0.60	2.73 ± 0.43*
Surface area (m²)	15.37 ± 3.28	15.18 ± 3.41	14.76 ± 0.52	13.51 ± 2.69
Cover (m²)	2.87 ± 0.35	0.33 ± 0.12**	3.29 ± 0.54	1.26 ± 0.26**
Maximum depth (m)	0.52 ± 0.03	0.25 ± 0.02**	0.57 ± 0.06	0.37 ± 0.03**
Mean depth (m)	0.27 ± 0.02	0.14 ± 0.01**	0.34 ± 0.04	0.21 ± 0.02**
Fish Resource				
Number	28.5 ± 3.8	11.3 ± 1.05**	12.4 ± 1.9	9.5 ± 1.49
Biomass (g)	460 ± 83	141 ± 30**	615 ± 88	319 ± 55*
Maximum size (mm)	185 ± 8	147 ± 10*	257 ± 13	199 ± 8**
Mean size (mm)	117 ± 2.6	98 ± 8.0	164 ± 12	142 ± 4*

[1]*Asterisks indicate significant differences between artificial and natural pools, * means P = 0.05, ** means P = 0.01.*

environments but has attained a length of over 450 mm in Christmas Tree Lake, Arizona (Rinne et al. 1981).

The greater mean size of Gila trout in McKnight Creek (table 1) relative to Main Diamond Creek and the more rapid growth rate in the former stream[3] may be related, in part, to the number of log structures per unit length of stream. Proportionally, Main Diamond Creek contains many more log dams (160 in 11 km) than does McKnight Creek (12 in 9 km). Gila trout in Main Diamond Creek appear to be stunted (Mello and Turner 1980), and this may reflect a response of the fish resource to habitat improvement. Regan (1966) suggested the small size of trout in Main Diamond Creek results from reduced summer flow. Unfortunately, no data are available for comparison between the present population and the population size and structure prior to installation of log dams in the 1930's. Nevertheless, I agree with Carufel (1964) that a few well-placed structures are better than mass installation and would disagree with the reasoning that if a few structures are good, many are better. Jester and McKirdy (1966) reported that stream improvement did not increase growth rate of a stunted population of brook trout. Although a different species, this suggests that the population of Gila trout in Main Diamond Creek is above optimum carrying capacity, and this may, in part, be attributable to excessive habitat improvement.

Based on studies of movement of Gila trout in these two streams relative to another (South Diamond Creek) that lacks stream improvement structures, it appears that log structures may restrict upstream movement of Gila trout.[3] This influence appears to be related to height of structures, but sufficient data have not been gathered to adequately evaluate height of structures versus their ascension by Gila trout. Double-log structures observed in New Mexico may reach a height of a meter or more above the downstream pool created by water plunge. The relationships of height of structure and habitat created (e.g., depth of pool) also are not available. Nevertheless, single-log structures do create excellent pools, are less expensive to construct, are more stable and resistant to destruction during increased streamflow and flooding, and, although not rigorously tested, must be more easily ascended by upstream spawning migrants.

Stream improvement appears beneficial for the habitat and population size and structure of Gila trout in these two small headwater tributaries. Despite this positive note, each stream for which structures are proposed must be evaluated separately. Contrary to most evaluations of such structures, Carufel (1964) did not record any increase in either angling pressure or harvest of trout after stream improvement in one stream in Arizona. Preferably, pre-evaluation should be conducted for stream reaches planned for improvement, including evaluation of fish and aquatic insect populations and general physical-chemical and habitat features such as cover, pool depths, streamside vegetation and pool-riffle ratio. In the headwater streams inhabited by the Arizona and Gila trouts, the often proposed 50:50 pool-riffle ratio may not be appropriate, but rather a 40:60 or even a 30:70 ratio may be optimum for the rearing of macroinvertebrates for fish consumption. I would recommend installation of a few well-placed, single-log structures, observation and evaluation for a designated time period, and then, if feasible, installation of additional structures. Ideally, hydrologists, engineers, fishery biologists, and landscape architects should jointly select sites.

Although habitat improvement through instream devices appears to be very beneficial to the number, size, and biomass of Gila trout, the cost of construction of these devices and their longevity must be evaluated alongside these increases in habitat and the fish resource. Jester and McKirdy (1966) estimated structures installed between the mid 1950's and 1960's cost about \$100 each. Today, the costs of installation and maintenance of log structures are much inflated. Estimates for log structures installed in the mid 1970's by the Mimbres Ranger District on Beaver Creek ranged between \$600 and \$700 per structure.[4] These were single-log structures and suffered a 25% loss in spring 1979 flooding. By comparison, 50% of the structures in McKnight Creek (most double-log) were lost to flooding in the winter of 1978 (personal observation). Surveys by personnel from the Gila National Forest in spring 1979 on Main Diamond Creek showed that 80 of 162 (ca. 50%) of log structures installed in the 1930's were in need of repair. Ehlers (1956) recorded a 75% loss over 30 years. Attrition of stream improvement structures will occur but is largely related to the nature of construction (one versus two logs) (USDA 1969) and perhaps, more importantly, to placement within the stream. Further, for the Gila trout immediate benefits of habitat improvement as yet cannot be realized by the angler because of the endangered status of the species.

Results of research on the effects of stream improvement structures on Gila trout may be applicable to the Arizona trout. However, preliminary habitat analysis in three streams in the White Mountains of Arizona suggests that in contrast to Gila trout, the Arizona trout was not a pool, but a riffle inhabitant. Four of 12 pools sampled contained no Arizona trout compared to only 1 of 11 riffles that lacked trout. A mean of only 2.25 Arizona trout per pool has been recorded in these three streams compared to an average of 7.3 fish per riffle. The number of trout in riffles is significantly greater ($P = 0.01$, $DF = 16$) when compared by an unpaired T-test. However, comparison of cover in the 12 riffles ($\bar{x} = 1.63$ m^2) to that in the 10 pools ($\bar{x} = 0.32$) indicated it also to be significantly greater ($P = 0.01$, $DF = 21$) when compared by an unpaired T-test. The lack of Arizona trout in pools, therefore, most likely resulted from a lack of cover. Based on the occurrence of significantly more cover and Gila trout in pools created by stream improvement structures, it appears that stream improvement also may be beneficial to the Arizona trout. Data do suggest, however, that creating better habitat for Arizona trout might necessitate improvement of riffle habitat and not creation of more pools by log structures.

[3]*Rinne, John N. In preparation. Movements of a rare southwestern salmonid relative to habitat and population density.*

[4]*Personal communication with Eddie Alfred, Range Conservation Officer, Gila National Forest, March 1980.*

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